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Case Study: Effects of Colostrum Ingestion on Lactational Performance[1]

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Abstract

*This study was designed to evaluate the effects of feeding two different volumes of colostrum immediately after birth on growth and lactational performance as growing heifers and lactating cows. Brown Swiss heifers were fed 2 L (n = 37) or 4 L (n = 31) of high quality (Grade 1) colostrum within the first hour of birth. Second and subsequent milk feedings were identical for both groups. Each animal received some colostrum daily for 14 d. Veterinary costs were approximately doubled for heifers fed 2 L of colostrum compared with heifers fed 4 L of colostrum. Those animals fed 4 L gained significantly greater daily BW compared with herdmates fed 2 L (1.03 ± 0.03 vs 0.80 ± 0.02 kg; P<0.001). Age at conception did not differ between the two groups of animals and was <14 mo. Animals fed 4 L of colostrum at birth produced significantly more milk compared with those fed 2 L (9907 ± 335 and 11,294 ± 335 kg vs 8952 ± 341 and 9642 ± 341 kg at first and second lactations, respectively) when lactation records were adjusted as 305-d mature equivalent (**ME**). Overall, feeding the greater volume of colostrum and then treating animals identically in terms of herd management translated into an advantage of 550 kg of actual milk produced per cow over the first two lactations. Herd managers should encourage the feeding of 4 L of colostrum to newborn calves because, in addition to health advantages that are well documented in past studies, there would be direct economic return to the producer of approximately $160 per cow in additional milk produced over two lactations.*

(Key Words: Calf, Colostrum, Growth, Health, Heifer, Lactation.)

Introduction

The importance of feeding newborn calves an adequate volume of high quality colostrum is well recognized. Maternal immunoglobulin (**IgG**) cannot traverse the placenta. Production of IgG by a newborn calf occurs at a rate of approximately 1 g/d from 36 h until 3 wk of chronological age (Devery et al., 1979). For passive immunity, a threshold concentration of 10 mg of IgG/mL in the serum of a calf that is 48 h old is recommended to reduce the incidence of health maladies (Donovan et al., 1986; Robison et al., 1988; Selim et al., 1995; Wells et al., 1996). Growth of calves also was affected by passive transfer (Nocek et al., 1984; Robison et al., 1988). Based on absorption of colostral IgG of 25% (Kruse, 1970), a calf needs to ingest approximately 100 g of IgG to attain the recommended 10-mg/mL threshold of serum IgG (Davis and Drackley, 1998). Because of variations in quality of colostrum (i.e., primiparous *vs* multiparous cows; Devery-Pocius and Larson, 1983), different volumes may be required for optimal concentrations of IgG. Feeding <2 L or feeding 2 L at 8 h after birth resulted in failure of passive immunity (Stott et al., 1979). Feeding 2 L of a low quality colostrum immediately at birth narrowly attained the 10-mg/mL threshold of serum IgG (Morin et al., 1997). Therefore, feeding 4 L of colostrum immediately at birth with bottles, esophageal feeders, or some combination of those, is encouraged. With that practice, based on the average concentration of IgG1 present in colostrum, 87% of first-milking colostrum should provide 100 g of IgG1 to calves (Pritchett et al., 1991; Davis and Drackley, 1998). The relationship between ingestion of colostrum and first lactation milk production has been estimated on the basis of quantifying Ig concentrations in blood of calves at 24 h after birth (DeNise et al., 1989). In that study, calves suckled their dams, so it was impossible to determine what volume of colos-

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trum each calf consumed. Nevertheless, regression analysis indicated that for each milligram of Ig detected/mL of blood at 24 h of age, milk yields increased by 8.5 kg when those calves became lactating first-calf heifers (DeNise et al., 1989). The purpose of this study was to evaluate prospectively whether force-feeding two different volumes of high quality colostrum immediately after birth translated into performance differences.

Materials and Methods

Animals. All experiments were conducted in accordance with the principles and guidelines presented in *Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching* (1999). All calves on the trial were born over a 26-mo period and were housed at Faber Swiss Colony farms in Ithaca, Wisconsin. Final milk production data were obtained prior to the year 2000. Sixty-eight Brown Swiss heifers from a diverse group of Brown Swiss sires were utilized in this study. Animals resided in individual pens in a barn equipped with side-curtains until weaning. Animals were housed together after weaning and received the same total mixed ration, including routine nutrient analyses, based on replacement heifer ration formulations created for the Faber Swiss Colony herd. The BW of each animal was estimated from heart girth measurements using a cloth tape measure (Heinrichs et al., 1992). Attempts were made to obtain BW for each animal at the time of calfhood vaccinations (approximately 4 to 6 mo). Body weight was also recorded on animals of all different ages on 1 d during the year at a time when the veterinarian was on the farm reviewing management practices with the operator. One measurement per animal was utilized to obtain a reference point to determine gains. Average daily gain was computed by subtracting birth weight (average = 41 kg) from the BW obtained at measurement, and that difference was divided by day of age.

Treatment. Heifers were randomly assigned to receive 2 or 4 L of colostrum at birth. Groups of heifers that were randomly assigned to the two treatment groups were sired by 12 and 10 different sires, respectively. Between the groups of heifers, there were four common sires. Quality of colostrum was determined objectively by specific gravity using a colostrometer (Biogenics, Napleton, OR). Colostrum was consistently analyzed at 38.5°C, and the same individual conducted each assessment to ensure repeatable results. Only colostral samples with a specific gravity in the green zone (Superior Grade 1; 50 to 140 mg of Ig/mL) on the indicator were used for first feedings. In the event that a calf's dam produced Moderate Grade 2 (20 to 50 mg of Ig/mL; yellow indicator) or Inferior Grade 3 colostrum (<20 mg of Ig/mL; red indicator), a previously frozen sample of Grade 1 material from an earlier lactation of a herdmate was thawed and fed to the newborn calf. Approximately 15% of the cows produced inferior grade colostrum. Every calf was force-fed within the first hour of birth; 37 calves received 2 L of colostrum, and 31 calves received 4 L of colostrum. Bottles were used for feeding, and the occasional calf that refused a bottle was fed with an esophageal feeder. Prior to esophageal feeding, attempts were made to feed each calf by bottle for 10 min. Although the esophageal groove is not closed, in which case colostrum would not bypass the rumen as a result of this management practice, slightly delayed absorption (3 h) does occur as colostrum moves from the reticulorumen to the abomasum with no documented adverse effects (Kaske et al., 2005). Depending on time of birth, the second feeding occurred within 12 h but no earlier than 4 to 5 h after the initial feeding for all calves in the study. Pooled colostrum from second and third milkings was used for four subsequent feedings for calves in both treatment groups. From that time through d 14 postpartum, each calf received one cup of pooled colostrums, which was added to 2 L of discard milk for each morning and evening feeding. After those 14 d lapsed, each heifer was fed warmed discard milk (without colostrum) and was offered high quality alfalfa and a calf starter mix (18% CP) until 7 to 8 wk of age, at which time they were weaned. From 2 to 4 mo of age, all calves were fed the same high quality alfalfa and a mix of high moisture shelled corn and a custom-made pellet with vitamins and minerals (18% CP).

Veterinary Costs. Health records were maintained individually for all calves. Every dam due to calve received ScourGuard 3® vaccine (Pfizer, Exton, PA) prior to calving, consistent with label directions on the product. Cost of that vaccine was included in the tabulation of medication costs for heifer calves that were subsequently born. Health disorders were diagnosed by the operator with confirmation and corresponding appropriate treatment prescribed by the veterinarian. Veterinary prescriptions could not be accurately assigned to each calf. Therefore, the total of veterinary products dispensed was tabulated as a cumulative inventory for each group of calves at the conclusion of the trial, and costs for those products were calculated based upon their value at the conclusion of the trial.

Statistical Analysis. Differences in ADG between calves fed the 2- or 4-L volume of colostrum at first feeding were computed using SAS® software (v. 8.2; SAS Inst., Inc., Cary, NC). Regression lines were fit to growth data [age (d) × BW (kg)] for each treatment group using Excel® software (2003; Microsoft, Bellevue, WA). Predicted BW (kg) for heifers in the 4-L treatment group was calculated at each age (d) of measurement using the Forecast command (Microsoft Excel, 2003) based on linear regression performed on the known growth curve of heifers in the 2-L treatment group. Differences between the predicted and actual BW were analyzed by ANOVA using Excel software.

Production averages for first and second lactations were analyzed by

TABLE 1. Health of Brown Swiss calves fed 2 or 4 L of colostrum at birth.

Treatment	Calves (no.)	Health disorders	Veterinary cost per calf ($)
2 L	37	8[a]	24.51
4 L	31	5[b]	14.77

[a]Pneumonia (n = 3), ulcers (n = 2), and poor health (n = 3).

[b]Corona virus (n = 4); navel infection (n = 1).

Proc Mixed procedures in SAS. Lactation length, as well as sire and dam milk predicted transmitting abilities (**PTA**) were used as covariates for analyzing actual milk production based on Dairy Herd Improvement Registry test-day weights. Additionally, 305-d mature equivalent (ME) records obtained at the end of each lactation were analyzed in the statistical model. Dependent variables were actual milk produced and 305-d ME milk. Independent variables were treatment, lactation number, treatment × lactation number, and the covariates stated. Level of significance was $P < 0.05$.

Results and Discussion

From data presented, the economic return to a producer force-feeding 4 L of high quality colostrum compared with 2 L would be substantial, generating approximately $160 per cow from increased milk production. Furthermore, veterinary costs from birth until first calving would be reduced approximately $15.00 per animal fed the greater volume of colostrum. Health information for calves fed 2 or 4 L of colostrum at birth is summarized in Table 1. The overall incidence of sick calves was similar for both groups of animals: 8 of 37 (21.6%) for heifers fed 2 L, and 5 of 31 (16.1%) for heifers fed 4 L. Actual health disorders varied (Table1), but there was no difference (P>0.05) in the frequency of health maladies as determined by Chi-square analysis.

Veterinary costs computed for the calves fed 2 L were approximately double ($24.51 per calf) compared with those fed 4 L of high quality colostrum ($14.77 per calf) within the first hour of life (Table 1). The increased costs incurred primarily because the nature of illnesses in calves fed 2 L of colostrum required repeated treatments and monitoring within animal. Septicemia was a common occurrence among unhealthy calves fed 2 L of colostrum, an indication that those calves failed to absorb adequate levels of protective Ig (Besser and Gay, 1985).

Age at conception and ADG for heifers fed 2 or 4 L of colostrum at birth are presented in Table 2. Average birth weight was 41 kg for all animals in the study. That birth weight is identical to the birth weight of 217 Brown Swiss calves in which the coefficient of variation on the 41-kg average was 2.3% (Villalba et al., 2000).

Animals fed 4 L of colostrum grew at a faster rate than their contemporaries fed 2 L, with ADG differing by 0.23 kg between the two groups of heifers (P<0.001). The BW of calves in both treatment groups at varying ages when those BW were taken are summarized in Figure 1. Regression equations for the growth responses were calculated, and the slopes of the two lines differed (P<0.01), indicating that the 4-L group displayed increased BW per day of age when examined up to approximately 500 d of age. An earlier study analyzing growth and survival of 1000 Holstein heifer calves reported that the concentration of serum Ig at 24 to 48 h affected ADG through the first 180 d of life (Robison et al., 1988). The importance of colostrum consumption is emphasized by multiple reports of a positive relationship between serum Ig and growth and health (Nocek et al., 1984; Donovan et al., 1986). In the current study, blood Ig was not measured, so a direct assessment of its effect cannot be determined; however, because high quality colostrum was fed to each treatment group, one could assume that the heifers fed the greater volume likely had greater concentrations of Ig, which could have contributed to increased growth and increased resistance to severe illness.

In terms of reproductive performance, both groups conceived at a similar (P>0.05) age (13.5 ± 1.6 *vs* 14 ± 1.6 mo; 2 *vs* 4 L, respectively). Age at first calving, similarly, did not dif-

TABLE 2. Age at conception and daily gain of Brown Swiss heifers fed 2 or 4 L of colostrum at birth.

Item	Age (mo) at conception	ADG[a] (kg)
	(Mean ± SEM)	
2 L (37[b])	13.97^{x} ± 1.6	0.80^{x} ± 0.02
4 L (31)	13.54^{x} ± 1.6	1.03^{y} ± 0.03

[a]Weights were estimated from heart girth measurements, and ADG was computed by dividing weight (minus initial BW) by day of age.

[b]Numbers in parentheses represent number of calves in study.

[x,y]Values with different superscripts within a column differ (P<0.001).

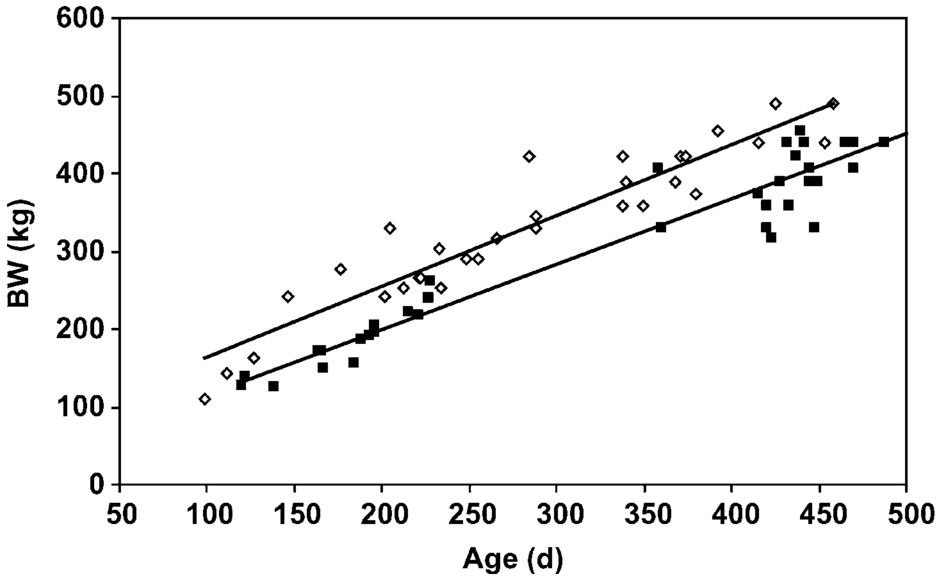

Figure 1. Growth of heifers fed 2 L (■; n = 37) or 4 L (◇; n = 31) of colostrum at birth varied (P<0.01). The top line represents weights (kg) of heifers receiving 4 L (regression equation: y = 0.92x + 71.2; R^2 = 0.89), and the bottom line depicts BW (kg) of heifers fed 2 L of colostrum (regression equation: y = 0.84x + 29.9; R^2 = 0.93). Each data point represents one measurement per animal.

fer (*P*>0.05) between the groups of animals in agreement with a previous study (DeNise et al., 1989) and was 23.1 mo overall (data not shown).

Milk PTA of sires was obtained at the conclusion of trial and did not differ between treatment groups. Dams of calves fed 4 L of colostrum had an average milk PTA of +66 kg compared with dams of the group fed 2 L of colostrum. That difference was adjusted for as a covariate as described in the statistical model. Lactational and genetic information for first and second lactations of cows fed the two different volumes of colostrum as newborn heifers is presented in Table 3. A total of 55 animals is included in the data. The reason for fewer animals in this analysis compared with growth data is that only records from those animals completing two entire lactations with complete covariate information were used in the analyses. Parenthetically, the number of animals fed 2 L of colostrum at birth that failed to complete two lactations was 9 of 37 (24.3%) compared with only 4 of 31 heifers (12.9%) fed 4 L of colostrum at birth. Five of the nine animals culled in the 2-L treatment group could be attributed to low milk production or udder health. Those limited data do not provide a definitive assessment, but they suggest that longevity of dairy heifers may be affected by colostrum intake at birth. Both actual and computed ME milk production were analyzed in the current study. Actual milk produced (kg) in the first lactation, adjusted for lactation length by covariate analysis, was similar for the 2-L and 4-L treatment groups (7848 ± 253 *vs* 7526 ± 252, respectively). The real value of feeding additional colostrum at birth was apparent in actual milk produced during the subsequent lactation (Table 3). In the second lactation, animals in the 4-L group produced 1349 kg more actual milk than did animals in the 2-L treatment group (*P*<0.05). For the duration of the trial, heifers fed 4 L of colostrum at birth produced approximately 1 kg of additional milk/d (actual) compared with cohorts fed 2 L of colostrum (27.8 *vs* 26.9 kg/d). Over both lactations, that additional 1 kg/d equated to 550 kg

TABLE 3. Least squares means (±SEM) for milk production[a], average lactation length, total milk during two lactations[b] (kg/d), and 305-d mature equivalent (ME)[c] (kg) of heifers fed 2 or 4 L of colostrum at birth.

	Volume of colostrum			
	2 L		4 L	
Item	Lactation 1	Lactation 2	Lactation 1	Lactation 2
Milk, kg	7848^{w} (253)	8167^{w} (249)	7526^{w} (252)	9516^{x} (251)
Lactation length, d	324 (9)	292 (13)	298 (5)	300 (8)
Total milk, kg/d	26.9		27.8	
305-d ME, kg	8952^{w} (341)	9642^{y} (341)	9907^{x} (335)	$11,294^{z}$ (335)
Sire PTA, milk, kg	+360 (38)		+347 (46)	
Dam PTA, milk, kg	+279 (39)		+345 (45)	
Heifers, no.	28		27	

[a]Least squares means for milk production (kg) produced by lactation were adjusted using lactation length as a covariate.

[b]Means for total milk (kg/d) produced by treatment were computed using actual milk produced during two lactations adjusted using dam predicted transmitting abilities (PTA) for milk as a covariate in relation to lactation length per treatment.

[c]Least squares means for 305-d ME milk (kg) produced during each lactation were adjusted using dam PTA for milk as a covariate.

[w,x,y,z]Means in a row with different superscripts differ (*P*<0.05) by treatment within lactation.

more milk produced by animals fed 4 L compared with herdmates fed 2 L of colostrum. That value is calculated on the basis of two, 305-d lactations using the mean difference (0.9 kg/d) in daily milk production. Genetic merit of sires of both groups of heifers was not different (P>0.05). Dams of calves fed 4 L of colostrum had greater genetic merit for milk production, and that was accounted for in the statistical model by way of covariate analysis.

In both lactations, animals fed 4 L produced significantly more 305-d computed ME milk compared with heifers fed 2 L of colostrum at birth. In the first lactation, animals in the 2-L group had 955 kg less (P<0.01) 305-d ME milk compared with those in the 4-L group. That difference escalated in the second lactation in which cows in the 2- and 4-L groups produced 9642 ± 341 and 11,294 ± 335 kg, respectively (P<0.001). Clearly, feeding the greater volume of colostrum to newborn calves led to superior milking performance as an adult. This is the second study to confirm a positive relationship between passive immunity of calves and lactational performance as mature animals. The earlier study (DeNise et al., 1989) utilized Holstein cattle, and colostrum intake was ascertained indirectly by assaying IgG content in blood of calves at 24 h postpartum. In this report, Ig content was unknown, but the contrast of utilizing a management practice to feed 4 or 2 L of high quality colostrum could be followed directly, as those animals remained in the herd so that performance measures could be monitored objectively.

Genetics is obviously an important consideration with any group of dairy cattle. The sires of heifers utilized in this project were genetically similar based on their PTA for milk. Dams of calves fed 4 L were superior in terms of their milk PTA, but, when that adjustment was included as a covariate in the statistical model, the 4-L treatment, overall, resulted in more actual and 305-d ME milk compared with the 2-L group. Four common sires occurred between the two treatment groups, but sire per se could not be included in the statistical analysis because three of those sires had only a singlet calf in one of the treatments. In follow-up research, efforts should be made to conduct trials where half-sibs (or full sibs from embryo transfers) receive 2, 3, or 4 L of colostrum at birth so a genetics × management interaction can be computed objectively. In that model, sires with varying PTA for milk should be selected.

An obvious question centers on what may be a normal constituent in colostrum that results in higher milk yields once heifers become lactating cows. From the data presented in Table 3 and an earlier report (DeNise et al., 1989), milk production at first lactation is proportional to the volume of colostrum that calves receive as newborns. There are no studies to support that IgG has an effect on mammary function per se. However, IgG could serve as a parallel indicator for some, as yet unidentified, colostral component that, when fed during the first few hours of life, leads to a significant increase in milk yield as mature animals.

Growth-promoting activity of mammary secretions has been reported in mammary cells and in epithelial-like cell lines cultured in vitro (Cera et al., 1987; Talhouk et al., 2001). The growth-promoting constituents present in colostrum may be related to proliferation and maintenance of the mammary gland, and their potential identity and physiological role has been the subject of previous studies (Shing et al., 1987; Iivanainen et al., 1992; Peri et al., 1992; Schams, 1994). Such activity in colostrum might be responsible for outcomes reported here as well as the earlier study (DeNise et al., 1989). Future experiments should be designed to fractionate colostrum to determine whether the component(s) responsible for enhanced mammary gland function as an adult can be identified. Hormones and growth factors that are likely candidates would be epidermal, transforming, and nerve growth factors as well as the hormones cortisol, insulin and thyroxine (Xu, 1996).

Implications

Heifer calves fed 4 L of high quality colostrum within the first hour of life had lesser veterinary costs ($15.00 per animal) and greater ADG, and they produced an average of 1 kg more milk/d across two lactations compared with cohorts fed 2 L of colostrum. At $0.29/kg ($13.00/cwt) for milk, approximately $160 more milk revenue (gross) would be returned per cow after two lactations if she was fed the higher volume of colostrum at birth. These findings justify encouraging calf feeders to feed 4 L of colostrum to calves of large dairy breeds as a standard management practice.

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